Vertical distribution of plant nematodes in an aquic brown soil under different land uses

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Abstract: The vertical distribution of the dominant genera of plant nematodes at the depth of 0–150 cm of an aquic brown soil were studied for four land use patterns, i.e., paddy field, maize field, fallow field and woodland in the Shenyang Experimental Station of Ecology, Chinese Academy of Sciences in November of 2003. The results showed that the numbers of some dominant genera under different land uses decreased with the increase of soil depth. *Helicotylenchus* was most dominant genus under each land use type. Genera of *Filenchus*, *Psilenchus* and *Tylenchus* in paddy field occurred at the depth of 0–20 cm; while *Paratylenchus* in fallow field and woodland, as well as *Pratylenchus* in maize field presented in the deeper soil layers (0–80 cm). Significant correlations between the numbers of dominant genera of plant nematodes and soil chemical properties were found in this study. The number of *Helicotylenchus* under different land uses was positively correlated with C/N ratio, total C, total N, total P, alkai-N, and Olsen-P. The numbers of *Filenchus* and *Paratylenchus* in paddy field, *Pratylenchus* in maize field and *Paratylenchus* in fallow field were negatively correlated with soil pH, and positively correlated with total C, total N and alkai-N. This study results showed that it is essential to sample at a certain depth according to the vertical distribution information of different genera of plant nematodes in adequately assessing the population size of plant nematodes.

Keywords: Vertical distribution; Plant nematodes; Dominant genera; Aquic brown soil; Land use
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Introduction

The research on relationships between land use and soil nematodes is essential for better understanding soil ecosystem process and adaptive ecosystem management (Ou *et al.* 2005). Many nematodes species were stratified in soil (Norton and Niblack 1991). The largest numbers of plant nematodes were found in the soil depth of 15–20 cm, but some might be found at a depth up to 240 cm (Raski *et al.* 1965). Root distribution might control the distribution of plant nematodes but was not the only factor (Norton and Niblack 1991). Different land uses have significant effects on the vertical distribution of plant nematodes. Sohlenius and Sandor (1987) reported that the numbers of *Helicotylenchu*, *Paratylenchus*, *Pratylenchus* and *Tylenchus* were significantly higher under grass than under barley at a depth of 0–40 cm, and the largest numbers of *Pratylenchus* and *Paratylenchus* under both grass and barley occurred at a depth of 10–20 cm. In semi-arid Mediterranean agroecosystems, the greatest numbers of *Tylenchorhynchus* in virgin soil were found at a depth of 0–19 cm, while those in cultivated soil were at a depth of 19–36 cm (López-Fando and Bello 1995). Verschoor *et al.* (2001) found that *Paratylenchus*, *Pratylenchus* and *Tylenchus* dominated at a depth of 0–10 cm and their numbers strongly decreased with the increase of depth, however, *Longidorus* and *Helicotylenchus* were prevalent in the deeper soil layers. Under agroforestry regimes down to 80-cm soil depth, *Paratylenchus* under *Pinus radiate* stand with a density of 400 stems·hm^{-2} only occurred at a depth of 0–10 cm (Yeates *et al.* 2000).

In order to effectively manage and regulate the population of plant nematodes in ecosystems, more evidence of different land uses on the vertical distribution of plant nematodes is required. There is no information on the vertical distribution of plant nematodes under different land uses in a CERN (Chinese Ecosystem Research Network) site of Northeast China. The objectives of the present study were: to determine the vertical distribution of plant nematodes under different land uses (paddy field, maize field, fallow field, and woodland); and to describe the relationships between plant nematodes and selected soil chemical properties in an aquic brown soil. The focus here will be on the dominant genera of plant nematodes within each land use type.

Materials and methods

Site description

This study was conducted at the Shenyang Experimental Station of Ecology (41°31′ N, 123°22′ E), Chinese Academy of Sciences, a Chinese Ecosystem Research Network (CERN) site at Sujiatun District, Shenyang Municipality, Northeast China. The station is located in the continental temperate monsoon zone, with a dry-cold winter and a warm-wet summer. The annual mean temperature is 7.0–8.0 ℃, annual mean precipitation is 650–700 mm, and annual non-frost period is 147–164 d. The soil at the study site is classified as aquic brown soil (Silty loam Hapli-Udic Cambosols in Chinese Soil Taxonomy), which is suitable for growing of maize, soybean, and rice (Ou *et al.* 2005). Before the establishment of the Station (1989), all the lands were paddy field with comparatively homogeneous fundamental soil fertility. In 1990, part of the lands was imposed to maize field, fallow field, and woodland (Zhang *et al.* 2004b) and continued to our sampling in 2003 (Ou *et al.* 2005).

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Soil sampling

In November 2003, soil samples were collected from four types of land use patterns, i.e., paddy (*Oryza sativa* L.) field, maize (*Zea mays* L.) field, fallow field, and woodland (*Populus canadensis*). Three replicated profiles for each land use pattern were excavated in a depth of 0–150 cm, which were divided into 0–5, 5–10, 10–20, 20–30, 30–40, 40–60, 60–80, 80–100, 100–120, and 120–150 cm layers (Zhang *et al.* 2004b). Subsamples were taken from each such bulk sample for estimation of plant nematode populations. Samples collected were kept at 4 °C before analysis.

Soil physiochemical measurements

Soil bulk density was determined by using stainless steel ring and oven-dried at 105°C. Soil total organic carbon (TOC), total nitrogen, alkali nitrogen, total P, Olsen-P and pH under the four land uses were measured by Zhang *et al.* (2004a, b).

Plant nematode extraction and identification

Plant nematodes were extracted from 100-g soil sample (fresh weight) using sugar flotation and centrifugation (Liang *et al.* 2001). The nematode populations were expressed as number of nematodes per 100 cm^3 of dry soil (Norton and Niblack 1991).

Number of nematodes was calculated by the following formula:

$$N_d = N_f \times (1+Y) \times 100/Z \text{ nematodes/100 g dry soil} \times \rho \text{ g/cm}^3 \quad (1)$$

where N_d is the number of nematodes per 100 cm^3 of dry soil, N_f is the number of nematodes per 100 g of moist soil, Z is the weight (g) of moist soil with a moisture content of Y (%), ρ is the bulk density (g·cm^{-3}).

All extracted nematodes in each sample were counted and identified to genus level using an inverted compound microscope based on stoma and esophageal morphology (Yin 2000; Liu 2000; Liang *et al.* 2001; Liang *et al.* 2003).

Statistical analysis

All the data were conducted to statistical analysis of variance (ANOVA) by the SPSS statistical package. Differences with $P <$ 0.05 were considered significant.

Results and discussion

Vertical distribution of dominant genera of plant nematodes

In this study, 9, 11, 14 and 13 plant nematode taxa were separately identified in paddy field, maize field, fallow field, and woodland. *Filenchus*, *Helicotylenchus*, *Paratylenchus*, *Psilenchus* and *Tylenchus* are dominant genera in the paddy field, *Helicotylenchus* and *Pratylenchus* dominant in the maize field, and *Helicotylenchus* and *Paratylenchus* are dominant in the fallow field and woodland (Fig. 1, Table 1).

Table 1. Correlation coefficients between dominant genera of plant nematodes and selected soil chemical properties under different land uses (n=30, respectively)

Land uses	Dominant genera	pH	Total C	Total N	Alkali-N	Total P	Olsen-P	C/N
Paddy field	*Filenchus*	–0.742**	0.534**	0.532**	0.492**	0.722**	0.227	0.395*
	Helicotylenchus	–0.229	0.503**	0.506**	0.528**	0.220	–0.020	0.462*
	Paratylenchus	–0.409*	0.522**	0.583**	0.517**	0.231	0.137	0.357
	Psilenchus	–0.263	0.477**	0.415*	0.416*	0.365*	0.026	0.450*
	Tylenchus	0.177	0.444*	0.396*	0.503**	0.103	0.238	0.455**
Maize field	*Helicotylenchus*	–0.761**	0.621**	0.651**	0.713**	0.257	0.162	0.394*
	Pratylenchus	–0.542**	0.701**	0.668**	0.667**	–0.350	–0.357	0.665**
Fallow field	*Helicotylenchus*	–0.652**	0.486**	0.455*	0.521**	0.069	–0.151	0.585**
	Paratylenchus	–0.668**	0.749**	0.726**	0.777**	0.148	–0.253	0.768**
Woodland	*Helicotylenchus*	0.585**	0.821**	0.838**	0.836**	–0.069	0.100	0.564**
	Paratylenchus	–0.057	0.015	0.021	0.031	–0.644**	–0.557**	0.032

Note: *, **: Significant at P<0.05 and P<0.01, respectively.

The dominant genera of some plant nematodes under different land uses decreased with the increase of soil depth. *Helicotylenchus* was most dominant genus under each land use type (Fig. 1). *Filenchus*, *Psilenchus* and *Tylenchus* showed similar trends under paddy field. More than 80% of *Filenchus*, *Psilenchus* and *Tylenchus* were found at a depth of 0–20 cm (Fig. 1 A, E, F); while 63% of *Filenchus* and 86% of *Psilenchus* were found at a depth of 0–10 cm in maize field (Fig. 1 A, E). The number of *Helicotylenchus* at a depth of 5–150 cm in fallow field was significantly higher than those in paddy and maize fields (Fig. 1 B). The number of *Paratylenchus* in fallow field was significantly higher than those in woodland, paddy and maize fields at all depths (Fig. 1 C), while the number of *Pratylenchus* in maize field was higher than those in the other land uses (Fig. 1 D). These results indicated that the greatest proportions of *Filenchus*, *Psilenchus* and *Tylenchus* in paddy field were in the uppermost layers (a depth of 0–20 cm), while those of *Pratylenchus* and *Paratylenchus* in fallow field were in the deeper layers (a depth of 0–80 cm) (Fig. 1 C, D).

The numbers of *Pratylenchus* at all depths in maize field of China were higher than those in rotation field of Spain. Crop rotation could effectively control *Pratylenchus* populations in the barley-sunflower field (López-Fando and Bello 1995). The vertical distribution of *Helicotylenchus* in fallow field was mainly at a depth of 0–40 cm, and greatest relative abundance was found at a depth of 20–30 cm (Fig. 1 C). These results were consistent with those of Verschoor *et al.* (2001) in a Dutch grassland (field K). The distribution of *Paratylenchus* in woodland was at a depth of 5–60 cm (Fig. 1 C). This result was not in line with that of Yeates *et al.* (2000), who found all of *Paratylenchus* populations in woodland at a depth of 0–10 cm. Perhaps differences of climate, soil and tree species between the two sites reflect the different vertical distribution of *Paratylenchus*.

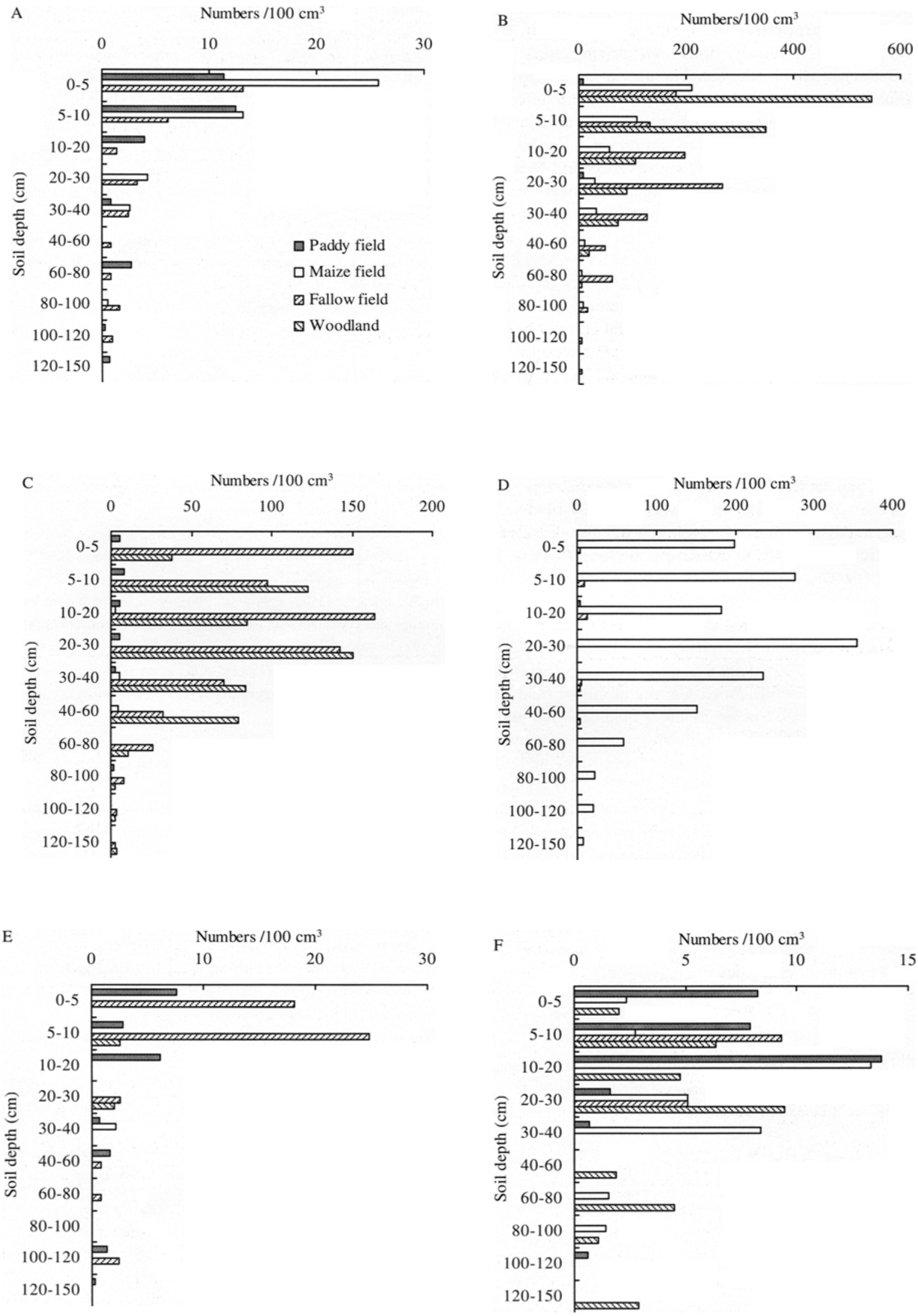

Fig. 1 Vertical distribution of dominant genera of plant nematodes under different land uses

A---*Filenchus*; B---*Helicotylenchus*; C---*Paratylenchus*; D---*Pratylenchus*; E---*Psilenchus*; F---*Tylenchus*

Correlation between numbers of dominant genera and selected soil chemical properties

The host plant is the most important driving force for plant-parasitic nematode populations, but abiotic factors are important in maintaining the steady state of plant nematode communities. Nematode communities often separate by abiotic soil factors (Norton 1989). The influence of soil properties on nematode populations may be direct or indirect (Norton and Niblack 1991). In this study, the correlations between dominant genera and soil chemical properties were calculated. The results showed that the number of *Helicotylenchus* under different land uses was positively correlated with C/N ratio, contents of total C, total N, total P, alkai-N, and Olsen-P (Table 1). The numbers of *Filenchus* and *Paratylenchus* in paddy field were negatively correlated with soil pH, and positively correlated with total C, total N and alkai-N. The same results were observed for *Pratylenchus* in maize field and *Paratylenchus* in fallow field (Table 1). These results indicated that higher contents of C and N conduced to the development of the above-mentioned dominant genera under different land uses, and a higher or lower value of soil pH was an important limiting factor for survival of the dominant genera. The numbers of *Filenchus* and *Psilenchus* in paddy field were positively correlated with total P, while the number of *Paratylenchus* negatively correlated with total P and Olsen-P (Table 1). The number of *Helicotylenchus* in woodland was positively correlated with soil pH.

To summarize, the different land use patterns had different effects on vertical distribution of plant nematode genera. *Filenchus*, *Psilenchus*, and *Tylenchus* in paddy field occurred at the soil depth of 0–20 cm; while *Paratylenchus* in fallow field and woodland, as well as *Pratylenchus* in maize field occurred in the deeper soil layers (0–80 cm). Significant correlations between the numbers of dominant genera of plant nematodes and soil chemical properties were found in this study. The C, N contents were positively correlated with most dominant genera under different land uses positively, while soil pH was negatively correlated with the dominant genera in both maize and fallow fields. This study results showed that it is essential to sample at a certain depth according to the vertical distribution information of different genera of plant nematodes in adequately assessing the population size of plant nematodes.

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